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THERMAL STRUCTURE AND ENERGY IN NORTH-EASTERN PART,CHINA

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Abstract

In North-eastern part of China the heat flow values are high in basins but low in mountains and old terrain(Erguna and Jiamusi Terrain). The correspondence among the Moho depth, high conductivity layers within the crust and upper mantle and heat flow can be found from the area. Using Cermark and Rybach's theory, the authors calculated the transformation of P wave velocity to the heat generation density, based on the refraction data. The calculated results can be used to estimate heat flow components of the mantle and crust on the terrains. These results show the differences in mantle heat flow among the terrains in the area. Mantle heat flows vary from west to east as follows: 23 mW/m^2 in the Erguna Terrain, 33 mW/m^2 in the Hailaer Basin, 33 mW/m^2 in the Da Hinggan Mountains, 50 mW/m^2 in the Songliao Basin, and 25 mW/m^2 in the Jiamusi Terrains. It is a fact that the mantle heat flow values are vary low in old Erguna and Jiamusi Terrains, Very high in the Songliao Basin, and middle in the Hailaer Basin and the Da Hinggan Mountains. We may draw the conclusion that the differences in geothermal structure of the crust and upper mantle cause the change in heat flow distribution among the terrains in the area. According to the calculated results, it is a fact that mantle heat flow and the stratum 10 km above or below in the crust in every terrain has different contributions to the surface heat flow. Geothermal resources in low-medium temperature geothermal systems of conductive type are mainly occurred in large-scale sedimentary basins, such as Songliao basin. Investigation and exploration demonstrate that Songliao basin is most promising area for development of low-medium temperature geothermal resources. In combination with the known geological and geophysical data the geothermal system structure model of the Changbai hot spring is established. The model shows that during the rising of the hot volcanic gas from a deeper magma in the center of volcanoes. It encounters the water percolated from the crater lakes and their surrounding area. The heated water then flows laterally and passes shallower subsurface. In mountainsides where faults well developed. The hot water rises and appears as surface geothermal occurrence.

1.Introduction

As well known, Heat flow is the vertical heat flux flowing through the crust per unit area and unit time. Heat flow values are closely related to deep thermal processes, deep dynamics processes and the crust and upper mantle structure. The heat flow data are useful in determining the thermal structure, thermal evolution and deep dynamic and can be used to interpret the structure of the crust and upper mantle. The study of heat flow distribution clarifies not only thermal structure and processes in the crust and upper mantle, but also origin of geologic structure, especially the basin structure. This study also reveals a constraint for deriving the paleogeotherm in the basin area with regard to oil and gas development, and provides important data useful for geothermal energy development.

2.Heat flow distribution

In this study, 81 heat flow values with detailed measurement data published so far in north-eastern part of China have been collected and used for the distribution and statistic analyses. The geographical distribution of the heat flow sites in the area is quite uneven; the heat flow values vary from 30-94 mW/m^2. Several static methods have been employed to calculate the average heat flow. The results indicate that the representative heat flow for the north-eastern continental area in China would be in the range of 60-63 mW/m^2. It is a common knowledge that heat flow measurement is limited by the distribution of drillings being used for temperature logging.

There is a shortage of measured heat flow values in the mountain area. The heat flow values in basins are high but low in mountains and old terrain(Erguna and Jiamusi Terrain) .

3.Geothermal energy

3.1 Low-medium temperature conductive geothermal system and resources

Geothermal resources in low-medium temperature geothermal systems of conductive type are mainly occurred in large-scale sedimentary basins. In north-eastern part of China, there exists one of such basins: Songliao basin.

In Songliao basin, the heat flow values vary from 40-90 mW/m^2, the average value is 70 mW/m^2. There is quite high heat flow background value. Calculated geothermal resource shows that the total thermal water amount is about 3.2×10^{12} m^3 (Chen et. al, 1994). Provided that one percent of the resources could be employed, the recoverable thermal water resources would be 3.2×10^{10} m^3,its thermal energy would be 3.7×10^{18} J(the reference temperature is 15℃), which amount to 1.26×10^{8} tons of standard coal equivalent. It has been employed now.

3.2 Hot spring distribution

In north-eastern part of China, along Tancheng-Lujiang deep-fault zone in E. Liaoning Peninsula, there exist about 30 hot springs with temperature 40℃-70℃, sometimes, up to 80℃-90℃. There exist 5 hot springs in Jilin province, one of the most famous is Changbai hot spring, which located in Changbai Tianchi volcanoes. In order to study the mechanism of Changbai mountains geothermal system developments, associated with Changbai mountains basaltic volcanic activity, Sino-Japanese scholars worked out geothermal surveys on Changbai hot spring area near the volcanic lake of Changbai mountains from 1996 to 1997. The temperature of Changbai hot spring is about 70-80℃, the highest reaching 81.6℃. The Changbai hot spring has also the largest flow rate reaching 6500 t/day. The heat discharge from the Changbai hot spring group, with a flow rate at 6500 t/day at an average temperature 61℃,is more than the heat energy released from burning 60 t standard coal. Geothermal energy resources development in Changbai Mountain area has a very broad future.

4. Conclusions and discussions

4.1 Geothermal structure based on analysis of heat flow

There is a close relation between Moho depth and heat flow. It is a general rule that the higher the heat flow value, the smaller the Moho depth is(Chapman, et. al. 1985). The moho surface, as located by refraction seismic survey along the transact from Manzhouli to Suifenhe in North-Eastern part of China(Jin Xu et. al. 1994) is about 40 Km deep in west Erguna Terrain, 37 Km in the Hailaer Basin, 33 Km in the Songliao Basin, and 39 Km in east Jiamusi Terrain. The scatter of the heat flow values above-mentioned corresponds to the Moho depth directly(Fig.1). The correspondence can be found easily in other areas in China(Jin Xu et. al. 1990).

The relation between heat flow values and the position of high conductivity layers within the crust(CHCL) and upper mantle(UMHCL) is close yet. This relation is presented in Adam's experienced equation: $h=h_0q^{-a}$, here h is depth of high conductivity layer, q is tectonic heat flow value, h_0 and a superscript are parameters which represent structure characters of an area. Fig.1 also shows the different depths to high conductivity layers which in the crust and the upper mantle, which are derived from the magnetotelluric sounding in the transact (Jin Xu et.al, 1994). The rising and falling of heat flow in the Da Hinggan and Zhangguangcai Mountains, where heat flow values have not been measured, can be outlined based on changes of the Moho depth and high conductivity layers in the crust and upper mantle.

There are obvious differences in the heat flow distribution between the Songliao Basin and Hailaer Basin. The values in the Songliao Basin are higher than those in the Hailaer Basin, and exceed the world average value (63 mW/m^2) (Lee,1970). That means a great difference in forming mechanisms and structure characters between the two basins. The existence of high heat flow values in the Songliao Basin is caused by three factors besides shallow Moho and the upper mantle (Wu

Qianfan et. al, 1985). Firstly, the Caledonian, Variscan and Austrian granites are distributed in the Songliao basin having high heat generation. Secondly, the Songliao Basin in East China is a part of rift valley series around the Pacific, and is a compound basin of rift and depression. The extension of the crust makes the heat movement active; finally, the Songliao Basin is a sealed stagnant basin. There is no sluice way in the area. The flowage of groundwater is slow and the flow velocity is only 6.1 mma^{-1}. Thus the heat can not escape easily. It is important that the large area covered by argillite formed by rapid lake immersion in the basin has batter natures of gathering and isolating heat. So the heat flow coming from deep earth could be conserved for a long time.

Fig. 1 also shows the differences in mantle heat flow among the terrains in the area. The values vary from west to east as follows: 23 mW/m^2 in the Erguna Terrain, 33 mW/m^2 in the Hailaer Basin, 33 mW/m^2 in the Da Hinggan Mountains, 50 mW/m^2 in the Songliao Basin, and 25 mW/m^2 in the Jiamusi Terrain. It is a fact that mantle heat flow values are very low in old Erguna and Jiamusi terrains, very high in the Songliao Basin, and intermediate in the Hailaer Basin and the Da hinggan Mountains. We come to the conclusion that differences on geothermal structure of the crust and the upper mantle cause the change in heat flow distribution among the terrains in the transect. According to the calculated results (Cermark, 1989), we know the fact that mantle heat flows in every terrain have different contributions to the surface heat flow.

There are two large basins in the area: the Songliao and The Hailaer Basins. However, there exist great differences not only in mantle heat flow, but also in geothermal structure of the crust between the two basins. They are not the same types. Mantle heat flow value is 50 mW/m^2 in the Songliao Basin, which is 60 percent as much as the surface heat flow value, It is 33 mW/m^2 in the Hailaer Basin, which is only 52 percent as much as the surface heat flow value. The great change in the values shows a great difference of the upper mantle geothermal structure in the basins. Their geothermal structure varies with the tectonic locations of basins. A Japanese scholar presented his study result after comparing the mantle structure with the history of plate underthrusting. The study is based on the theory of seismic topography (Maruyama et. al, 1993). Following his view we obtain the interpretation of forming high mantle heat flow values in the Songliao Basin: a piece of the pacific retentive cold plate subducts into the mantle below Songliao Basin. When the piece falls from the upper mantle to the lower mantle, heat plume produced in the mantle will rise upward to compensate for the fall. The rising movement of " hot " plume probably has formed high mantle heat flow in the Songliao Basin. Calculated geothermal structure within the crust shows that the upper crust of the upper most above 10 Km contributes much more to the surface heat flow (22 mW/m^2) than that in the lower crust of the lower most 10 Km (9 mW/m^2) in the Songliao Basin. On the other hand, the contribution of upper and lower crust are roughly equal in the Hailaer Basin (they are 16 mw/m^2 and 14 mW/m^2, respectively). The fact reveals that the enrichment of heat generative radioelements toward the surface is larger in the Songliao Basin, but the enrichment is less in the Hailaer Basin. Paying attention to lithologic characters, we find that the difference degree among acid, basic and ultrabasic rocks in the Songliao Basin is higher than that in the Hailaer Basin. The above-mentioned situations are consistent with the fact that huge granitic intrusive probably exist in the depth range from 5 to 13 Km beneath the Songliao Basin(Wu Qianfan et. at, 1985).

4.2 Geothermal resources

Geothermal resources in low-medium temperature geothermal systems of conductive type are mainly occurred in large-scale sedimentary basins, such as Songliao basin. Investigation and exploration demonstrate that Songliao basin is most promising area for development of low-medium temperature geothermal resources.

In combination with the known geological and geophysical data the geothermal system structure model of the Changbai hot spring is established (Fig.2). The model shows that during the rising of the hot volcanic gas from a deeper magma in the center of volcanoes. It encounters the water percolated from the crater lakes and their surrounding area. The heated water then flows laterally and passes shallower subsurface. In mountainsides where faults well developed. The hot water rises and appears as surface geothermal occurrence.

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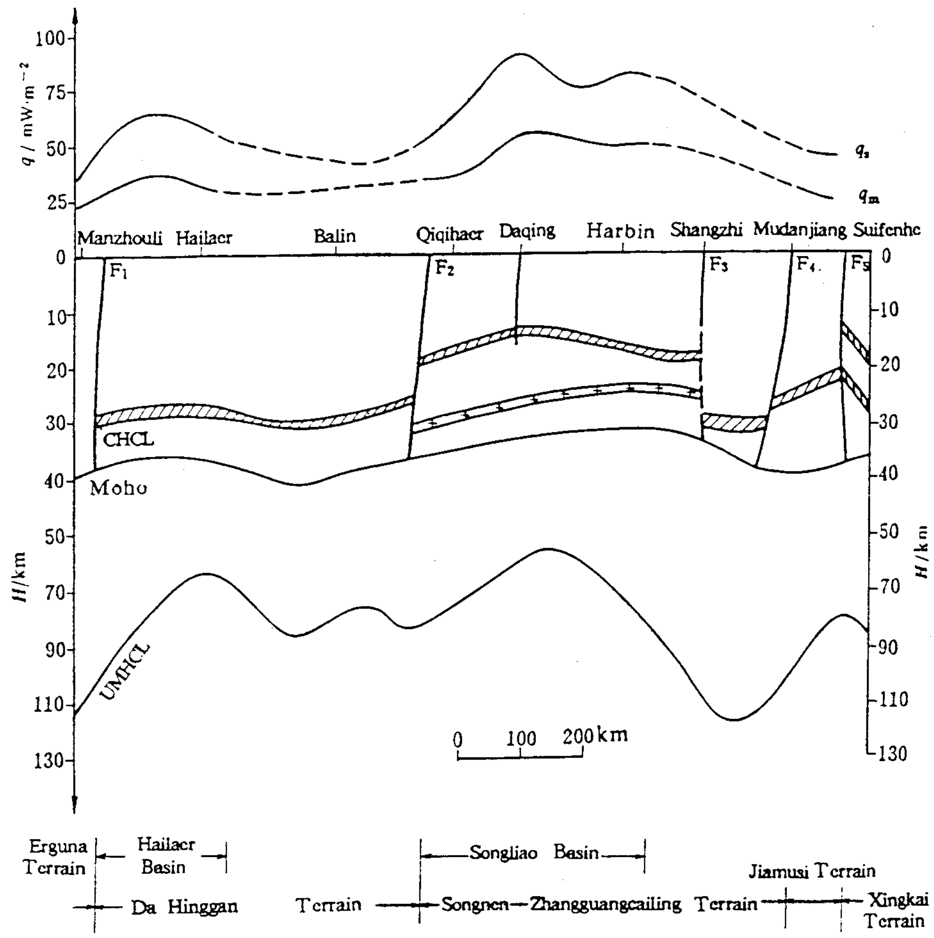

Fig. 1. Changes in geosurface heat flow, mantle heat flow and geological structure along the transect. F_1, Deerbugan Fault; F_2, Nenjiang Fault; F_3, Jiayi Fault; F_4, Mudanjiang Fault; F_5, Dunmi Fault.

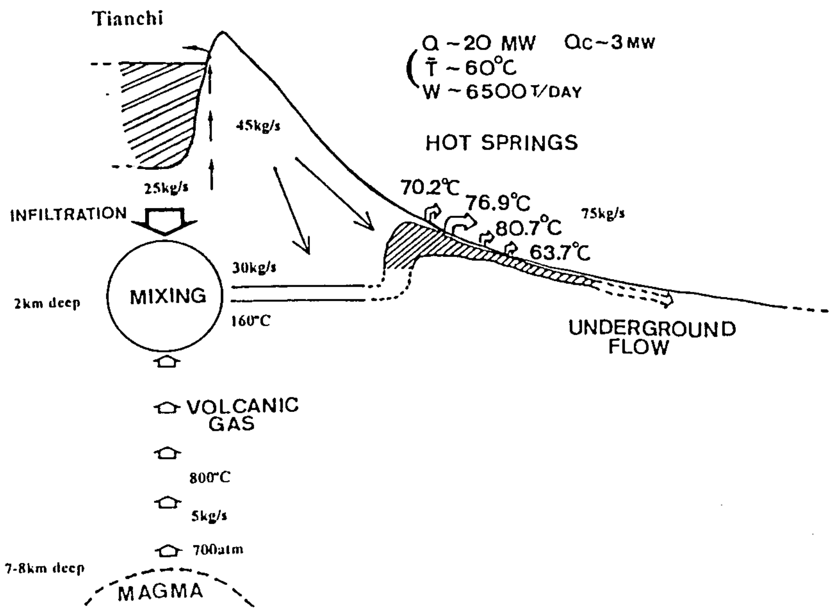

Figure 2. A conceptual thermal model beneath the hot spring area at the flank of Changbaishan volcano